Oil & Natural Gas Technology

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Quarterly Progress Report
(04/01/08 – 06/30/08)

Gas Storage Technology Consortium

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National Energy Technology Laboratory

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Office of Fossil Energy

DISCLAIMER

ABSTRACT

Gas storage is a critical element in the natural gas industry. Producers, transmission and distribution companies, marketers, and end users all benefit directly from the load balancing function of storage. The unbundling process has fundamentally changed the way storage is used and valued. As an unbundled service, the value of storage is being recovered at rates that reflect its value. Moreover, the marketplace has differentiated between various types of storage services and has increasingly rewarded flexibility, safety, and reliability. The size of the natural gas market has increased and is projected to continue to increase towards 30 trillion cubic feet over the next 10 to 15 years. Much of this increase is projected to come from electric generation, particularly peaking units. Gas storage, particularly the flexible services that are most suited to electric loads, is crucial in meeting the needs of these new markets.

To address the gas storage needs of the natural gas industry, an industry-driven consortium was created – the Gas Storage Technology Consortium (GSTC). The objective of the GSTC is to provide a means to accomplish industry-driven research and development designed to enhance the operational flexibility and deliverability of the nation's gas storage system, and provide a cost-effective, safe, and reliable supply of natural gas to meet domestic demand.

This report addresses the activities for the quarterly period of April 1, 2008 through June 30, 2008. Key activities during this time period included:

- Hosting the 2008 GSTC Spring Meeting, Chicago, IL, on April 17-18, 2008;
- Identifying the co-funded project;
- Drafting a Request for Proposals for Fall 2008;
- Beginning a transitional planning effort;
- Preliminary planning and identifying the meeting site for the 2008 GSTC Fall Meeting;
- Drafting the *GSTC Insider* e-newsletter;
- Submitting the 2004, 2005, and 2006 final reports to DOE for public posting;
- Receiving and posting the final report for the 2006 project, Storage Field Well-bore Flow Data Containing Water and Hydrates.

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INTRODUCTION

Gas storage is a critical element in the natural gas industry. Producers, transmission and distribution companies, marketers, and end users all benefit directly from the load balancing function of storage. The unbundling process has fundamentally changed the way storage is used and valued. As an unbundled service, the value of storage is being recovered at rates that reflect its value. Moreover, the marketplace has differentiated between various types of storage services and has increasingly rewarded flexibility, safety, and reliability. The size of the natural gas market has increased and is projected to continue to increase toward 30 trillion cubic feet over the next 10 to 15 years. Much of this increase is projected to come from electric generation, particularly peaking units. Gas storage, particularly the flexible services that are most suited to electric loads, is crucial in meeting the needs of these new markets.

To address the gas storage needs of the natural gas industry, an industry-driven consortium was created – the Gas Storage Technology Consortium. The objective of the GSTC is to provide a means to accomplish industry-driven research and development designed to enhance the operational flexibility and deliverability of the nation's gas storage system, and provide a cost-effective, safe, and reliable supply of natural gas to meet domestic demand. Consortium technology development is conducted in the general areas of well-bore and reservoirs, operations, mechanical, and salt caverns. Consortium members elect an executive council that is charged with reviewing projects for consortium co-funding. Projects are submitted by GSTC members and are funded on an annual basis. Proposals must address improving the production performance of gas storage and provide significant cost sharing. The process of having industry members develop, review, and select projects for funding ensures that the GSTC conducts research that is relevant and timely to the industry.

The scope of Penn State's activities includes managing the process of attracting and maintaining consortium members, soliciting proposals, awarding and monitoring subcontracts to members to accomplish the selected technical works and disseminating the results of the technical work via meetings and final reports.

EXECUTIVE SUMMARY

This report summarizes the important accomplishments during the period of April 1, 2008 through June 30, 2008. The GSTC was established under contract to The Pennsylvania State University from the U.S. Department of Energy (DOE), National Energy Technology Laboratory (NETL), in June 2004. The agreement provides the Pennsylvania State University with the overarching management responsibilities for the GSTC. Key activities for this reporting period included the following:

2008 GSTC Spring Meeting

The 2008 GSTC Spring Meeting was held at the Embassy Suites Chicago Downtown Lakefront, Chicago, IL on April 17-18, 2008. The meeting was dedicated to hearing new proposal requests, as well as technology updates from current projects. A strategic planning session was also part of the session.

2008 Co-funded Project

The Executive Council recommended one project for co-funding at the 2008 GSTC Spring Meeting. Testing for the Dilation Strength of Salt, RESPEC will be funded for the period of July 1, 2008 to June 30, 2009.

2008 Request for Proposals

The 2008 Request for Proposals for the Fall 2008 was drafted and will be released early next quarter. All proposals received will be heard at the 2008 Fall Meeting, Washington DC on October 21-22, 2008.

Transitional Planning

Based on input from the GSTC members at the 2008 Spring Meeting, a Transitional Planning Team has been identified to create a transitional plan to be presented at the 2008 Fall Meeting.

2008 GSTC Fall Meeting

The GSTC has identified the Embassy Suites, Washington DC as the meeting site for the 2008 GSTC Fall Meeting on October 21-22, 2008. The meeting will be a technology transfer meeting, unveiling the draft transitional plan, special speakers, as well as hearing all proposals received in response to the Request for Proposals.

GSTC Insider E-newsletter

The *GSTC Insider* e-newsletter was drafted for release next quarter. This is the second newsletter in 2008 and offers an additional mechanism for keeping the industry informed.

Storage Field Wellbore Flow Data Containing Water Hydrates Final Report

The final report for the 2006 project, Storage Field Wellbore Flow Data Containing Water Hydrates (Colorado Engineering Experiment Station) project was received and posted in the member's only section of the website.

2004, 2005, and 2006 Final Reports Submitted

Fourteen final reports from 2004, 2005, and 2006 projects were submitted to DOE for posting to the public website.

EXPERIMENTAL

A description of experimental methods is required by the DOE for all quarterly technical progress reports. In this program, Penn State is responsible for establishing and managing an industry-driven underground gas storage consortium. Technology development research awards are made on a competitive basis. Technical reports from the individual researchers are required to contain experimental discussion sections and are submitted to consortium members and the DOE for review. Therefore, this section is not applicable to the Penn State contracted activities.

RESULTS & DISCUSSION

This report addresses the activities for the reporting period from April 1, 2008 through June 30, 2008. Key activities during this time period included:

- Hosting the 2008 Spring Meeting, Chicago, IL on April 17-18, 2008;
- Identifying the co-funded project and subcontract negotiations;
- 2008 Request for Proposals drafted;
- 2008 GSTC Fall Meeting preliminary planning;
- Transitional Planning;
- *GSTC Insider* e-newsletter drafted;
- One final report for a 2006 project received; and
- 2004, 2005, and 2006 final reports submitted to DOE for posting to public website.

GSTC Administration

The scope of the GSTC administration activities includes managing the process of attracting and maintaining consortium members, soliciting proposals, developing strategies for action on recommendations from the technical committee and executive council, keeping the industry informed on issues and events, and awarding and monitoring subcontracts to members to accomplish the selected technical works.

2008 GSTC Spring Meeting

The GSTC hosted the 2008 GSTC Spring Meeting at the Embassy Suites Chicago Downtown Lakefront, Chicago, IL on April 17-18, 2008. Due to only receiving two funding requests, the meeting was primarily a technology transfer meeting dedicated whereby eight projects offered technology results. A strategic planning session was held to gather suggestions and comments on how the GSTC can better serve the industry. It was decided to identify small core group to create a transitional plan. The transitional plan will be presented at the Fall Meeting. At the close of the general meeting, the Executive Council met and recommended one proposal to go forward. The agenda is attached at Appendix A.

2008 Co-funded Project

The GSTC Executive Council recommended one project, The Testing for the Dilation Strength of Salt, RESPEC, for co-funding at the 2008 Spring Meeting. The period of performance will be July 1, 2008 to June 30, 2009. This project proposes to focus on improving the methodology for defining the onset of dilation for rock salt. The objective is to determine if substantially more information can be derived from a single specimen by subjecting the specimen to multiple load paths. The results will lead to an improved methodology for determining acceptable minimum operating pressures and increased confidence in geomechanical assessments of salt caverns used for natural gas storage. The Executive Summary is attached as Appendix B.

2008 GSTC Request for Proposals

The 2008 GSTC Request for Proposals for the Fall was drafted and will be released early next quarter, with proposals due October, 2008. Proposals are sought in the following focus areas:

- Mechanical
- Well-bore and reservoir
- Operations
- Salt cavern
- White paper to compare and contrast gas wells with CO_2 sequestration

Transitional Planning

The GSTC is seeking ways to better serve the industry. During the Spring Meeting, the membership offered several areas of possible focus including: CO_2 Sequestration, LNG, and expanding internationally. A core group from the GSTC membership has been identified to assess suggestions and create a transitional plan. The plan will be presented at the fall meeting.

2008 GSTC Fall Meeting

The GSTC administration has identified the Embassy Suites Washington, Washington DC for the 2008 GSTC Fall Meeting on September 21-22, 2008. The meeting will be an opportunity to hear all funding requests received as well as technology developments from current projects. The results from the transitional plan will be presented, in addition to presentations from special invited speakers.

GSTC Insider **E-newsletter**

The *GSTC Insider* electronic newsletter was drafted for release early next quarter. This is the second newsletter for 2008 and is another method of keeping representatives informed on issues relevant to the industry. The newsletter is distributed to the GSTC list serve as well as being posted to the GSTC website.

Technology Transfer/Outreach

There are several avenues for accelerating the commercialization and deployment of technology into industry. The GSTC strategy includes meetings to hear technology updates from co-funded projects, software training, and disseminating the final research results in a timely manner.

Storage Field Wellbore Flow Data Containing Water and Hydrates Final Report

The final report for the 2006 project, Storage Field Wellbore Flow Data Containing Water Hydrates Final Report, (Colorado Engineering Experiment Station) has been received and posted to the GSTC member's only section of the website. The report is attached as Appendix C.

2004, 2005 and 2006 Final Project Reports Submitted

The final reports for 2004, 2005 and 2006 reports were submitted to DOE for posting on the website. Fourteen reports were submitted and are available at:
http://www.netl.doe.gov/technologies/oil-gas/publications/Storage/NT41779_FinalReports2004-2006.pdf
The reports are:

2004 Project Final Reports

- Gas Storage Field Deliverability Enhancement and Maintenance:
- An Intelligent Portfolio Management Approach, *West Virginia University*
- Real Time Well Bore Integrity Modeling, *Colorado School of Mines*
- Renovation of Produced Waters from Underground Natural Gas Storage Facilities:
- A Feasibility Study Using Hybrid Constructed Wetland Technology,
- *Clemson University*

2005 Project Final Reports

- Cement Evaluation in Gas Filled Borehole, *Baker Hughes*
- Demonstration-Scale Constructed Wetland System for Treatment of
- Produced Waters from Underground Gas Storage, *Clemson University*
- Using Chemicals to Improve Gas Deliverability, *Correlations Company*

- Temperature Effects on Threaded Couplings in Caverns, *RESPEC*
- New Comprehensive Inventory Analysis Tool, *Schlumberger Data and Consulting*
- Wellbore Cement Bond Integrity, *University of Texas at Austin*
- Gas Storage Field Deliverability Enhancement and Maintenance: An Intelligent
- Portfolio Management Approach, Phase II, *West Virginia University*

2006 Project Final Reports

- Predicting and Mitigating Salt Precipitation, *Correlations Company*
- State-of-the-Art Assessment of Alternative Casing Repair Methods, *Edison*
- *Welding Institute*
- Wellbore Cement Bond Integrity, *University of Texas at Austin*

Planned Activities for Next Reporting Period

During the next quarter the GSTC will:

- Release the Request for Proposals;
- Continue with Transitional Planning;
- Continue planning for 2008 Fall Meeting, Washington DC on October 20-22;
- Identify a mentor team for the RESPEC project awarded during last quarter;
- Release the online newsletter.

CONCLUSIONS

During this reporting period, the GSTC hosted the GSTC 2008 Spring Meeting in Chicago, IL. One project was identified for co-funding for 2008-09. The Fall Request for Proposals has been drafted. The meeting site for the 2008 Fall Meeting has been identified and preliminary planning for the meeting has begun. The *GSTC Insider* e-newsletter was drafted for release early next quarter. The final report for the 2006 project, Storage Field Wellbore Flow Data Containing Water Hydrates Final Report, (Colorado Engineering Experiment Station) was received and posted to the member's only section of the GSTC website. Final reports for fourteen projects from 2004, 2005 and 2006 were submitted to DOE for posting on the website. Through these efforts, the GSTC continues to improve and better serve the gas storage industry.

REFERENCES

A listing of referenced materials is required by the DOE for each quarterly technical progress report. However, this technical progress report for the GSTC did not utilize any reference materials during this reporting period.

APPENDICES

Appendix A – 2008 GSTC Spring Meeting Agenda

Appendix B – Testing for the Dilation Strength of Salt Executive Summary

Appendix C – Storage Field Wellbore Flow Data Containing Water and Hydrates Final Report

Appendix A
2008 GSTC Spring Meeting
Agenda

GSTC SPRING MEETING

Embassy Suites Chicago Downtown Lakefront
Chicago, IL

April 17, 2008	
8:30 am	**Registration – Ohio Rooms Numbers 1 & 2**
8:45	**Opening Remarks and Introductions**
9:00	Proposal: **Managing Salt Cavern Growth via Salinity Control** Presenter: *Correlations Company*
9:30	Proposal: **Testing for the Dilation Strength of Salt** Presenter*: RESPEC*
10:00	**The Penetration Power of Ultrasonic Guided Waves for Piping and Well Casing Integrity Analysis** Presenter: *The Pennsylvania State University*
10:30	**Break**
11:00	**Brine String Integrity-Case History Survey and Model Evaluation** Presenter: *PB Energy Storage Services, Inc.*
11:30	**Gas Storage Facility Design Under Uncertainty** Presenter: *University of Texas at Austin*
12:00	**Lunch - Atrim**
1:00	**Evaluation of Magnetic Pulse Welding (MPW) for Improved Casing Repair** Presenter: *Edison Welding Institute*
1:45	**Smart Gas: Using Chemicals to Improve Gas Deliverability – Phase II** Presenter: *Correlations Company*
2:30	**Break**
3:00	**Strategic Planning**
	Day 1 Wrap-up

April 18, 2008	
8:15 am	**Registration – Ohio Rooms Numbers 1 & 2**
8:30	**Effects of Tensile Loading on the Remaining Strength of Corroded Casing** Presenter: *Kiefner and Associates*
9:00	**Predicting and Mitigating Salt Precipitation-Phase II** Presenter: *Correlations Company*
9:30	**Technical Feasibility Evaluation of Non-Intrusive Optical Detection, Monitoring and Preliminary Characterization of Casing Cement Leaks for Gas Wells** Presenter: *URS Group, Inc.*
10:00	**Meeting Wrap-up**
10:15	**Executive Council Session Begins – Wabash River Room**

Appendix B
Testing for the Dilation Strength of Salt
Executive Summary

PUBLIC EXECUTIVE SUMMARY

Testing for the Dilation Strength of Salt

Kerry L. DeVries
RESPEC
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A laboratory testing program on rock salt specimens is proposed using test conditions that are consistent with the stresses that are experienced near the cavern surface during storage operation. The proposed work effort focuses on improving the methodology for defining the onset of dilation for rock salt. Geomechanical studies use dilation criteria to assess the potential for salt damage that can lead to spalling in the cavern roof and/or walls and subsequent damage to the cavern or hanging string. This constraint is often the one that limits the minimum gas pressure in a natural gas storage cavern.

Currently, RESPEC uses the constant mean stress test to provide experimental data that are used to establish a dilation criterion for the host salt formation. The constant mean stress test, as currently performed, uses a single load path for assessing the propensity of salt to dilate. The test is performed by increasing/decreasing the axial stress and confining pressure simultaneously in a manner that maintains the mean stress constant. By maintaining a constant mean stress, elastic volumetric strain changes are suppressed in the test. The volumetric strain is monitored during the test and is used to determine the stress state that induces salt dilation (volume expansion caused by microfracturing). A typical testing program requires that several tests be performed to span the range in mean stress expected in the salt surrounding the cavern during gas storage operation. The tests are performed under triaxial compression and triaxial extension states of stress. Test conditions are often repeated to determine the response of different salt cores under identical conditions, further increasing the number of tests performed. Variability in the test results limits the confidence in establishing the dilation criterion, especially if only a limited number of tests are performed.

The objective of this project is to determine if substantially more information can be derived from a single specimen by subjecting the specimen to multiple load paths. Additionally, testing of specimens having different length-to-diameter (L:D) ratios are planned to assess the possible effect of L:D on the constant mean stress test results under triaxial extension states of stress. Results of this research will lead to an improved methodology for determining acceptable minimum operating pressures and increased confidence in geomechanical assessments of salt caverns used for natural gas storage.

Appendix C
Storage Field Wellbore Flow Data Containing Water and Hydrates Final Report

Storage Field Wellbore Flow Data Containing Water and Hydrates

Phase I Final Report

3193-CEES-DOE-1779
DOE Cooperative Agreement DE-FC26-03NT41779

Flow Test Section for Hydrate Constrictions and Blockages in Wellbores

June 1, 2006 through May 31, 2007

Prepared by:

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May 25, 2008

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Disclaimer

This report was prepared by Colorado Engineering Experiment Station, Inc. (CEESI) as an account of work cosponsored by CEESI and the Gas Storage Technology(GSTC), neither CEESI nor members of the GSTC, nor any person acting on behalf of either:

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Assumes any liability with respect to the use of or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

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Storage Field Wellbore Flow Data Containing Water and Hydrates

Executive Summary

Phase I Report

Flow Test Section for Hydrate Constrictions and Blockages in Wellbores

The objective of this project was to obtain full-scale experimental flow data on the development of hydrate blockages in natural gas storage field wellbores and subsurface flow control valves. A CEESI hydrate flow test facility and associated flow data was to be developed to replicate the hydrate flow conditions that occur in wellbores when hydrate constrictions and blockages are developing. The original objective of this project was significantly scaled back by GSTC due to the priority and funding level provided for this work.

CEESI has completed the construction of its hydrate wellbore flow test facility phase, i.e. Phase I work. The new test section permits identifying the means to minimize hydrate constrictions and blockages in the wellbore. It further allows identifying mitigation methods for wellbore flow blockages. CEESI's wellbore hydrate flow test facility gives the industry the basis for significantly improving gas storage field hydrate safety procedures and wellbore flow control options.

This report is for Phase I. The Phase I goal was to design, construct, and validate flow in the wellbore flow test section at the CEESI Hydrate Flow Test Facility. It extends CEESI's existing flowlines, instrumentation and fluid handling capabilities to the new hydrate wellbore flow test section. The work has included safety/leak testing, operation validation, and data acquisition system installation/verification. All of the goals of Phase I have been achieved. The new test section is fully operational. The installation, fluid injection and flow, pressure testing, and data acquisition system testing of the hydrate wellbore test section was completed during March 2008. Operation validation was completed during April 2008. The Phase I report to GSTC was completed during May 2008.

There are four recommendations made based on this work. First, it is recommended that wellbore flow data be obtained at the CEESI HFTF Wellbore Flow Test Section. Second, it is recommended that member companies of the Gas Storage Technology Consortium join an independent CEESI consortium to obtain such data. Third, it is recommended that CEESI HFTF consortium review meetings be held at CEESI where the hydrate flow test facility is located. The meeting can be held in conjunction with complementary upstream production meetings. Those meetings are important to hydrate flow, monitoring and control. The industry meetings are held annually in Estes, Park, Colorado in the later part of July. Gas storage operators would benefit by participating in it. The fourth and final recommendation is that storage field operating companies provide hydrate prevention, monitoring and control training to their personnel. The training can be provided at CEESI where relevant training with hydrate and fluid control would prove insightful and valuable to CEESI consortium participants and their field personnel.

Lastly, it is important to recognize that project scheduling risks at the CESSI flow facility, as originally stated to GSTC by CEESI, labor constraints, and nominal co-funding produced delays in the completion of the Phase I work. The Phase I report demonstrates that despite these constraints, CEESI completed the work and has performed beyond expectations. CEESI, as the principal operator, stakeholder and majority cofunder, is satisfied with the installation of the new wellbore hydrate flow test section, its performance and its unique capabilities. CEESI has completed the Phase I work and achieved all of the objectives. This has been accomplished despite obstacles presented to it. CEESI welcomes the opportunity to elaborate on the principal issues associated with this work to any GSTC gas storage field operating member company who may be interested in understanding the issues associated with this project - upon their request.

Storage Field Wellbore Flow Data Containing Water and Hydrates

Phase I Final Report
3193-CEES-DOE-179

Flow Test Section for Hydrate Constrictions and Blockages in Wellbores

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Hydrate Test Facility Modifications for a Wellbore Flow Test Section

1. Introduction

Natural gas hydrates are common whenever water is present in production, gathering, transmission, and processing flow lines. They cause severe capital and labor intensive challenges to operators. Hydrates are formed whenever natural gas and water are in contact at the hydrate formation equilibrium condition in flow lines. Hydrate related problems include flow constraints, flow blockages, measurement errors, equipment malfunctions and damage, flow shut-ins, and, in extreme cases, catastrophic failure to flow line equipment. Safety is a paramount consideration when hydrates are present. As fluids and operating environments become more severe, hydrate control becomes an increasingly important component in assessing safety, capital and operating risks.

Hydrate blockages occur in the production tubing, at subsurface safety valve, at the well head, at the inlet to a separator, upstream of the orifice, downstream of the orifice, instrument lines, in the liquid drips and in the gathering and trunk lines where fluids accumulate. Blockages in gas storage fields can lead to the shut-in of a well, multiple wells, or, in severe cases, a trunk line. The consequences of the shut-in depend on the operating characteristics of the facility. In all cases shut-ins create an undesirable condition for the operator because it constrains the facility's ability to respond to requests from gas control. The development of a flow blockage is difficult to predict, monitor, control, locate and alleviate. The problem is exacerbated due to inadequate field instrumentation, fluid measurement, separation equipment, chemical injection monitoring and flow control. Anecdotal evidence from operators indicates that many storage field flow line blockages do not occur under gas withdrawal and injection conditions, i.e. gradual choking of the lines through growth on the pipe walls. Rather, flow line blockages are promoted during gas injection, after sustained shut-in periods, and on start-up during withdrawal periods.

Hydrate formation and blockages are frequent occurrences in natural gas storage fields. Hydrates block gas flow, create significant safety problems for field personnel, damage equipment, increase costs, and seriously limit gas deliverability for storage field operators throughout the year. They often occur following extended shut-in periods and at start-up during injection and withdrawal, and gas cycling. In order to meet natural gas demand during peak winter months, gas storage field facilities must operate at conditions that cause hydrates to form in their flow lines. Hydrates cause economic, maintenance, safety, and operating problems in storage field wells, flow lines and nearly all related equipment. These problems manifest themselves in gas deliverability and efficiency constraints which are most evident when the demand for gas is the greatest and of most value to the storage field operator. Depending upon the location of the blockage significant revenue may be lost during high demand periods. Demand charge refunds may be imposed on storage field operators if gas deliverability is constrained. Residential, commercial and industrial end-users cannot afford peak delivery interruptions due to weather and process condition requirements. As gas demand pressures increase and field automation efforts extend to more gas storage fields, there is a growing need for the ability to provide low cost technologies to prevent, minimize, detect and control hydrate accumulations in the gas storage field. Hydrate problems in storage facilities are not restricted to high demand cold weather periods, they occur throughout the year.

The CEESI Hydrate Flow Test Facility (HFTF) is unique. It is the dedicated to hydrate flow testing for gas storage operators. Previous tests at CEESI have clearly demonstrated how hydrates are formed and transported in flow lines. The hydrate flow studies included water saturated natural gas, natural gas with free liquid water, natural gas/liquid water/solid hydrate, and natural gas/liquid water/liquid condensate /solid hydrate flow. The test conditions included steady and unsteady flow data at surface and subsurface operating conditions. Tested temperature conditions range from near wellhead fluid injection temperatures to flow line wall temperatures that are well below the ice point. The tests included full-scale horizontal, inclined, and bench scale vertical (simulated riser) flow line configurations. The hydrate flow data from the CEESI HFTF show that the formation of a hydrate blockage in storage field flow lines is highly dynamic. Blockages may not be a single blockage but may consist of multiple hydrate mass accumulations and blockage points. Decomposition of one blockage can create problems with other hydrate mass accumulations. Recent CEESI work has expanded the bench scale riser study to include hydrate flow behavior in a full scale wellbore and subsurface safety valve configurations. The quality and quantity of data that CEESI has obtained on hydrate flow at gas storage field operating conditions is significant. It has provided the single most important and useful data on hydrate formation, transport and blockage development for gas storage field operations.

Hydrate wellbore flow data for gas storage field operations do not exist. Hydrate flow data that demonstrates how hydrate blockages develop in storage field wellbores and associated subsurface safety valves are clearly important to the industry. The goal of CEESI's hydrate flow data program is to provide comprehensive hydrate flow data set for gas storage field wellbore operations. The results are expected to be used by storage field operators to identify hydrate management options for reducing wellbore and subsurface control valve hydrate constriction and blockage risks. The overall objective of the research work is to obtain experimental wellbore hydrate flow data at different flow rates and loadings within the hydrate formation and blockage region. The results can be expected to be immediately useful to operators since it provides direct measurements on hydrate flow and blockage behavior problems.

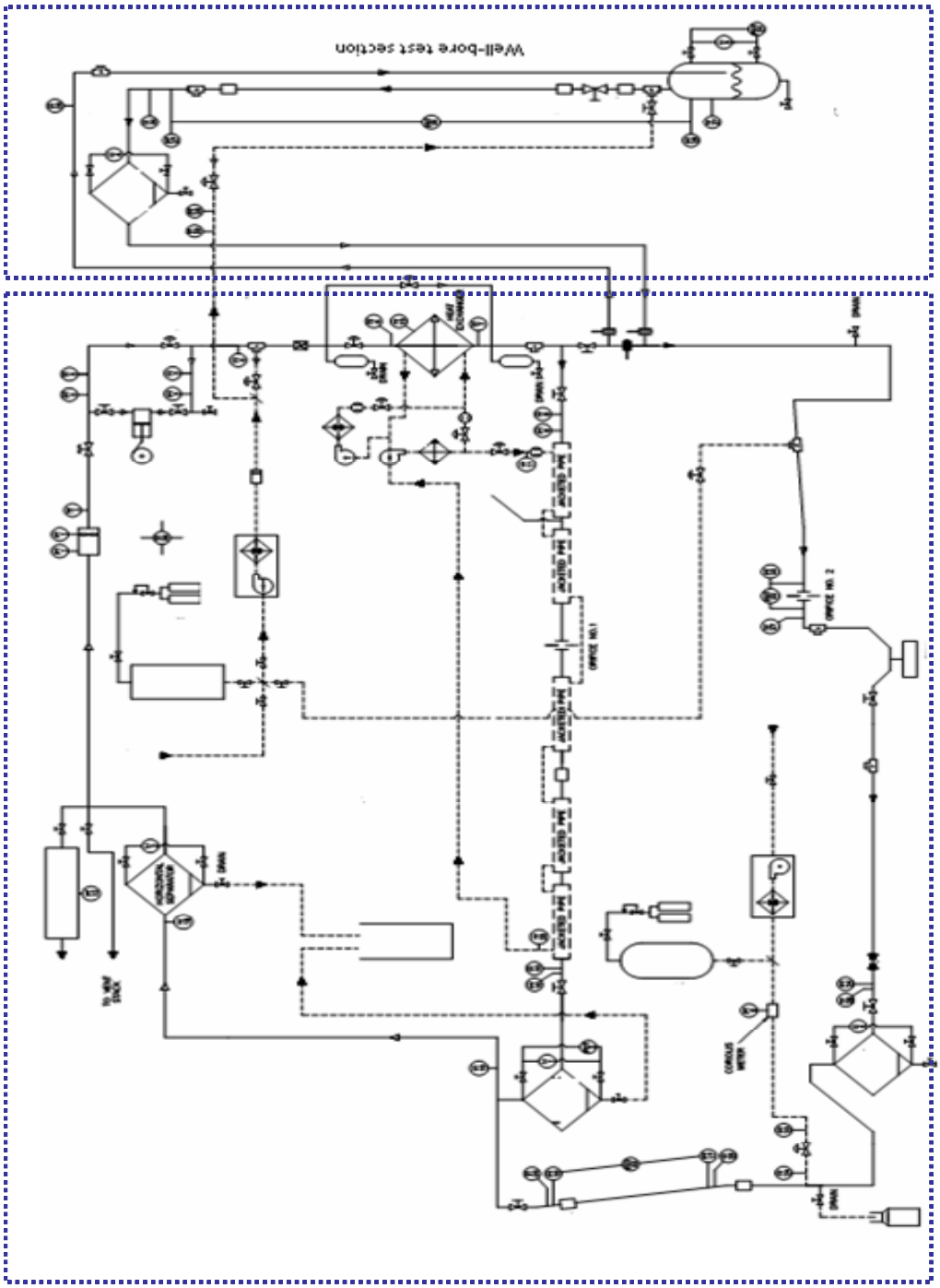
The work reported here completes Phase I of CEESI's Storage Field Wellbore Flow Data Containing Water and Hydrates entitled "Hydrate Flow Test Facility Modifications for a Wellbore Flow Test Section". The report focuses on the design, construction, installation, and shakedown verification of CEESI's hydrate wellbore flow test section. The new test section is a significant expansion of CEESI's HFTF.

2. Design test section extension of the CEESI hydrate flow test facility

A new wellbore test section has been designed and constructed at the north-east corner of the CEESI's HFTF. It extends from the beginning of the south bound leg of the non-isothermal flow loop to the north east corner. The distance to the entrance of the wellbore test section from the compressor and chiller is approximately 100' and consists of 4" diameter buried pipe. Section 2.1, figure 1, provides the flow and control schematic and piping layout. It also shows the connection of the wellbore test section to the existing hydrate flow test facility.

2.1. Piping layout

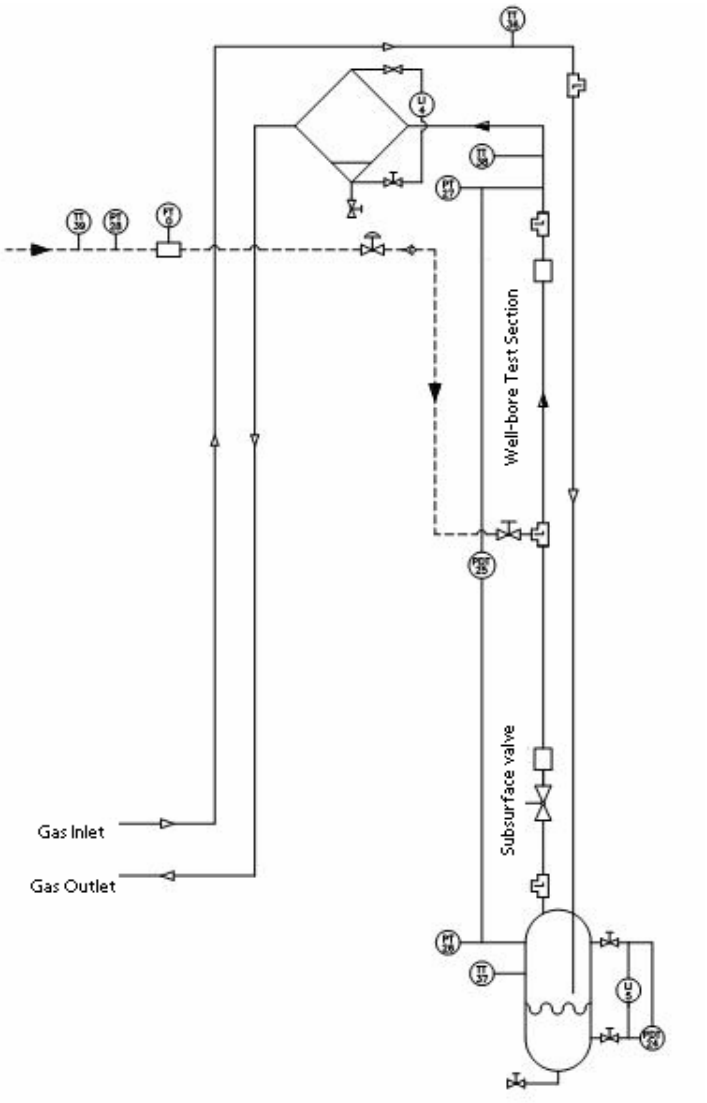
Figure 1. CEESI Hydrate Flow Loop showing location of the wellbore test section.



2.2. Instrumentation layout

The instrumentation on the wellbore test section consists of typical flow monitoring equipment including pressure and temperature transmitters, fluid level sensors, and CEESI's imaging devices. The instrumentation is shown in the wellbore test section schematic provided in Figure 2.

Figure 2. CEESI's hydrate wellbore flow test section with instrumentation layout.



3. HFTF modifications

The following figures document the modifications that were made to the CEESI HFTF to support obtaining data for gas storage wellbore hydrate flow studies per the GSTC and its participating gas storage operator member companies. Figure 3 through Figure 19 show the different phases of the work carried out at the CEESI facility for Phase I. The images are self-explanatory.

3.1. Piping Installation

The design and installation of the inlet and return flow lines to the new wellbore test section included multiple elements. Briefly, those elements included: (1) junction to the existing facility, (2) ground excavation to wellbore site, (3) installation of subsurface flowlines, (4) burying the flowline extention, (5) wellbore site modifications, (6) approximately 50 ft. wellbore construction, (7) wellbore installation, (7) separator installation, and (9) wellbore and separator junction connection to wellbore extension flowlines.

Figure 3.Wellbore hydrate flow test section flow line site – view from main loop

Figure 4. Wellbore hydrate flow test section flow line site – view from wellbore location

Figure 5. Wellbore hydrate flow test section flow line subsurface installation excavations

Figure 6. Wellbore hydrate flow test section junction with main loop

Figure 7. Wellbore hydrate flow test section flow line excavation to wellbore site

Figure 8. Wellbore hydrate flow line installation at wellbore location.

Figure 9. Wellbore installation location.

Figure 10: 4" subsurface inlet and return extension junction from existing hydrate flow facility to wellbore test section.

Figure 11: Completed Wellbore test section inlet and return flow line junction to main loop.

3.2. CEESI 4” x 54’ Wellbore hydrate flow test section

Figure 12. Assembled wellbore test section with control valve and instrumentation.

Figure 13. Wellbore test section prior to installation in subsurface site.

Figure 14. Wellbore hydrate flow test section being installed in to subsurface site.

Figure 15. Top down view of installed wellbore hydrate flow test section.

Figure 16. External connections of wellbore test section and surface separator.

Figure 17. Welding of connection from separator to fluid flow lines

Figure 18. Inspection of welding connections from separator to flow lines.

Figure 19. Completed Wellbore test section, inlet and exit flow lines, and GLCC separator.

3.3. Installation of instrumentation ports

Multiple instrumentation ports were installed in the wellbore test section. The instrumentation locations are visible in figure 2 and figure 13. They provide locations where the temperature, pressure, differential pressure and fluid flow rates can be monitored via CEESI's data acquisition system. In addition, spools were included that permit in-situ video monitoring of the flow state as a function of the operating conditions.

4. Safety and flow validation

4.1. Pressure tests

The extensions to the CEESI wellbore test section was externally pressure tested prior to installation in the test site and then internally tested in the wellbore after installation. All pressure and safety testing met CEESI's maximum allowable operating pressure specifications. No leaks were detected prior to installation, following installation or during flow verification of the test section.

4.2. Fluid validation

Fluid injection was tested at different injection points in the wellbore test section. Fluid flow was observed and monitored. No fluid leaks were observed. Gas flow control passed all shakedown flow testing. Test conditions included typical operating conditions in the 900 psia and 45°F operating range similar to those used in previous hydrate flow testing conducted at CEESI.

4.3. Data acquisition validation

The data acquisition was installed and the system tested at CEESI. It functions properly, as in previous hydrate flow testing. Data acquisition passed all shakedown performance tests performed at CEESI.

4.4. Test section evaluation

The new wellbore test section meets the design objectives and has demonstrated that it permits the evaluation of hydrate flow and blockage development in wellbores. The CEESI HFTF Wellbore Test Section operation shakedown testing was completed during April 2008. Additional chilling capacity was added by CEESI to facilitate temperature control operations. CEESI personnel indicated that care must be exercised during flow testing operations to insure that hydrates do not plug critical flow control points in the wellbore test loop equipment.

5. Conclusion

The CEESI HFTF Hydrate Wellbore Test Section is complete and is functioning as designed. The wellbore test section is unique and permits evaluation of hydrate formation, flow, constriction, blockage, and remediation efforts in wellbore environments and configurations for gas storage fields. In addition, it includes appropriate fluid separation technology evaluation capabilities at the exit from the wellbore. The wellbore site is highly accessible and permits easy modifications to accommodate changes as required by wellbore fluid and flow control work.

Preliminary test data demonstrated the test section provides superior performance. It has exceeded CEESI's performance expectations. CEESI's wellbore hydrate flow test section is fully operational.

The installation, fluid injection and flow, pressure testing, and data acquisition system testing of the hydrate wellbore test section was completed in March 2008. Subsequent operation shakedown tests were completed in April 2008. The Phase I report to GSTC was completed in May 2008.

6. Recommendations

It is recommended that specific field related wellbore flow data be obtained at the CEESI HFTF Wellbore test section. It is further recommended that member companies of the Gas Storage Technology Consortium join an independent CEESI consortium to obtain such data. The data will only be made available to participating member companies. The location of consortium meetings will be held in Colorado, at or near the CEESI hydrate flow test facility, i.e. the location where wellbore hydrate flow and blockage field related data are being produced and can be directly observed by consortium participants. It is further recommended that CEESI consortium review meetings be held in conjunction with other practical upstream meetings. Those meetings are important and complementary to the hydrate flow, monitoring and control work. The meetings address key aspects of flow measurement, monitoring (e.g. well testing related measurement) and control. They include critically important gas, wet gas and multiphase flow measurement. The industry meetings are sponsored by CEESI and are held annually in Estes, Park, Colorado - typically in the later part of July. It is further recommended that the storage field operating companies provide their field personnel with relevant hydrate measurement, monitoring and control training. Relevant, hands on training with hydrate and fluid control will prove insightful, useful, and valuable to CEESI consortium participants and their field personnel.

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